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Radiation Safety Implications of the Proposed Main Ring/Energy Doubler Abort

J. D. Cossairt

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This is a review of the radiation safety implications of the Main Ring/Energy Doubler abort dump as proposed by T. E. Toohig on September 7, 1979. Particular emphasis in the review is placed on the inclusion of uranium metal in the dump.

The code CASIM[1] was used to calculate the internuclear cascade in such a dump in order to determine various quantities of interest. For these calculations, 3 forms of the abort were used; one of which specified the geometry of the problem approximately as it has been proposed while the other 2 replaced the uranium with the same volume of iron and lead. In all cases, the calculation was run for an incident beam energy of 1000 GeV. The abort was assumed to be a single dump instead of a combination of 2 dumps. The geometry used as input to the code is shown in Fig. 1. I also assume that 1×10^{18} protons per year will be incident on the abort. Perhaps a more realistic estimate is that 3.5×10^{17} protons per year would be aborted.[2] The principal results of the calculations are displayed in Fig. 2, 3, and 4.

1. <u>Dose Rate in Outdoor Areas</u>:

If the dump is at the main ring level, el 725.5', a reasonable berm top elevation is 747' or at a radius of 655 cm. Extrapolating from the worst place at R=300 cm using the known attenuation length of soil, the star density in the worst place on top of such a berm is:

$$SD_{max}(Fe) = 2.3 \times 10^{-13} \text{ stars/(cm}^3 \cdot \text{proton)}$$
$$SD_{max}(Pb) = 2.3 \times 10^{-13} \text{ stars/(cm}^3 \cdot \text{proton)}$$
$$SD_{max}(U) = 1.5 \times 10^{-13} \text{ stars/(cm}^3 \cdot \text{proton)}$$

The above numbers are equal when the probable error in the calculation is taken into account. One should be aware that standard CASIM underestimates the star density in a material with large atomic number such as ^{208}Pb or ^{238}U.[3] The $SD_{max}(Fe)$ implies that at 5×10^{13} protons/pulse, 20 sec. cycle time, a dose rate of 19 mrem/hour would be measured on top of such a berm over the dump. The CO location is about 5500' from Butterfield Road and the top of the berm is already 22 feet from the source point so that the dose on Butterfield is 0.03 mrem/year at 1×10^{18} protons/year. This is quite low compared with the Laboratory's limit of 10 mrem/year for any off-site location.

Of course, off-site muons could be a problem. However, this beam dump is relatively deep in the ground. Van Ginneken has calculated muon dose rates for such cases in which an iron dump is followed by a thick soil shield.[4] The site boundary at Butterfield Road is 5500' from CO along the tangent to the main ring and the road is at el. 740' or 440 cm radially. From Ref. 3 at such an intensity one obtains a muon dose rate of 0.7 mrem/year.

This estimate is quite conservative since it represents a $1/r^2$ extrapolation from the results of Ref. 4 for a distance of 3900 feet from the source (the largest such distance considered in Ref. 4) and neglects the ranging out of muons in the additional soil shield encountered here. At 1000 GeV the range in muons in soil is as low as 1.32×10^5 centimeters (4330 feet) if all likely energy loss mechanisms are involved.[5] A 6 foot tall person standing 5500 feet from CO at elevation 740 feet would be shielded by about 4400 feet of soil at his waist with the result that all of the muons would be ranged out. Of course, there being no data at 1000 GeV, reliance on the muons all being ranged out might be overly optimistic. However, the 0.7 mrem/year estimate is certainly conservative. One comparison which can be made for the 3 possible core materials is their contribution to multiple scattering. The Moliere theory has recently been verified to be sufficiently accurate for our purposes at energies as high as 175 GeV for Cu and Pb targets.[6] Using the standard form of the Moliere theory and assuming 100 GeV incident muons, the three materials give the following rms projected angles:

Fe: 1.65 mrad

Pb: 2.92 mrad

U : 3.89 mrad

So that if the Fe core gives a dose rate of 0.7 mrem/year, the Pb core gives a dose rate of 0.2 mrem/year while the U core gives a dose rate of 0.13 mrem/year at the site boundary.

2. Soil Activation

If the stars produced in the unprotected soil are summed, one obtains the following:

Fe: 0.408 stars/proton

Pb: 0.248 stars/proton

U : 0.107 stars/proton

The antiproton target area is at a similar elevation and has been the subject of extensive calculations which give the result that 2.5×10^{17} stars/year yields the maximum soil activation allowed.[7] At 10^{18} protons/year, the dump with Fe is approximately a factor of 1.6 over the limit while the dump with U is about 50% of the limit. The dump with lead is equal to the limit. However, if only 1 foot more concrete or an equivalent thickness of iron (about 4 inches) surrounds the dump on all sides, the dump with Fe produces only

0.2 stars/proton in the unprotected soil (2×10^{17} stars/year) and hence is with the limits.

3. Plutonium Production:

The amount of ^{239}Pu produced was estimated crudely using the results of a study of the possibility of energy production using accelerators by R. R. Wilson.[8] The spectrum of hadrons incident on the upstream end of the U is shown in Fig. 5 and has an average momentun of 3.3 GeV/c and a flux of 8.8×10^{-3} hadrons/cm^2·proton) or a total beam of about 16 hadrons/ (incident proton). Scaling the results of FN-298 to the lower momentum, one obtains about 1 gm/year of Pu which, if all taken to be ^{239}Pu, represents an activity of 0.07 Ci. If other Pu isotopes are present, the activity will be higher because of the shorter half lives.

4. Summary

These results do not indicate sufficient benefit to justify the presence of the uranium. This is based upon the result that all dose rates are estimated to be comfortably within the Laboratory and DOE guidelines. While the inclusion of the uranium would reduce the off-site muon dose rates, the dose rates calculated for Fe or Pb cores are acceptable and are readily measured. Detection of any plutonium leakage would be much more difficult. The use of lead would help the off-site muon problem (if indeed there is a problem) and the soil activation problem.

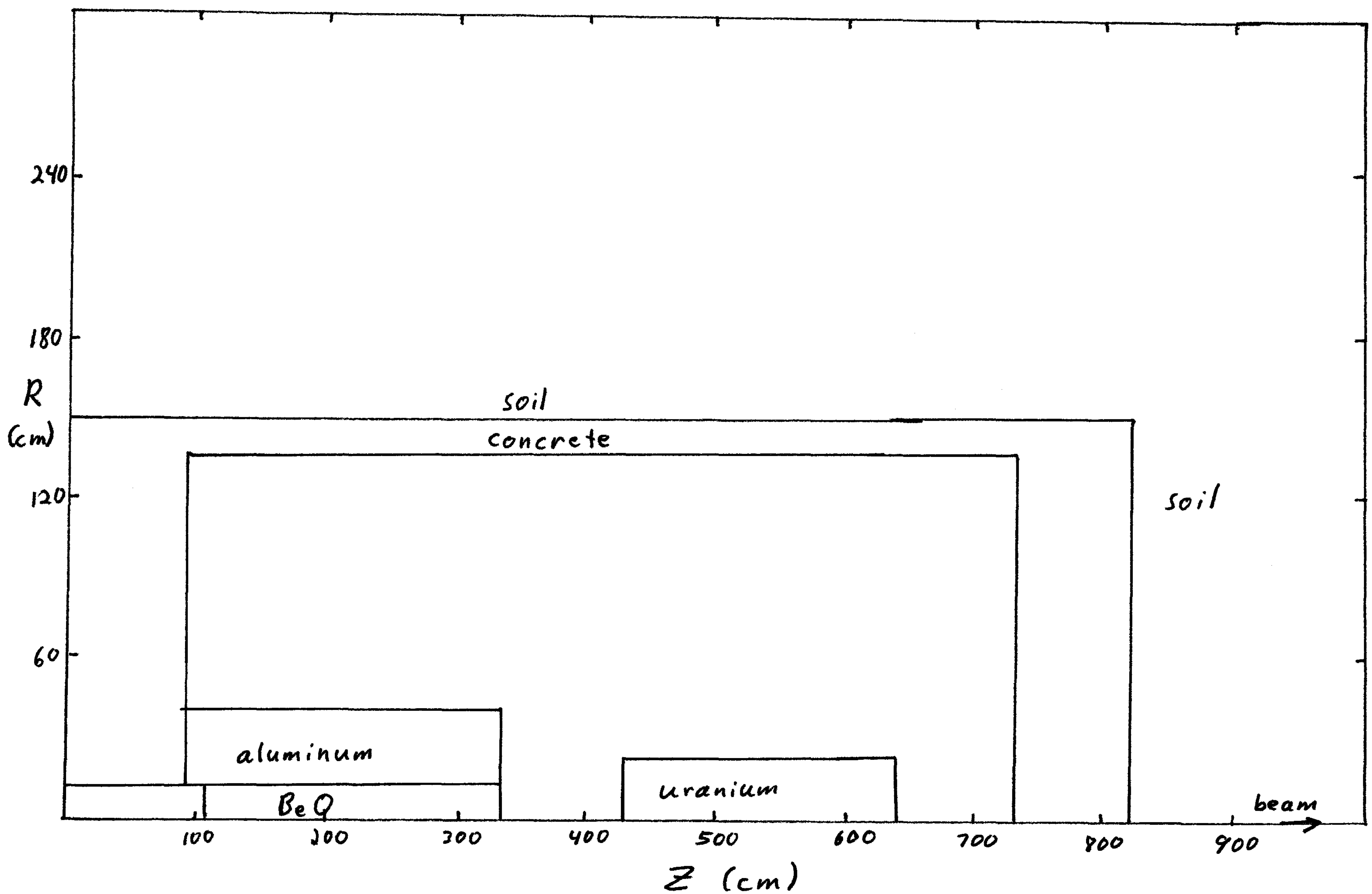
The soil activation problem can readily be solved in the case of Fe by slightly enlarging the abort if iron is used. No such adjustment is needed if the abort is limited to 5×10^{17} protons/year.

REFERENCES

1. A. Van Ginneken, FN-272.
2. H. T. Edwards, private communication.
3. A. Van Ginneken, TM-652.
4. A. Van Ginneken, TM-630.
5. D. Theriot, TM-229 and G. Koizumi, TM-786.
6. G. Shen, et.al., Phys. Rev. D (to be published).
7. P. J. Gollon, TM-816.
8. R. R. Wilson, FN-298.

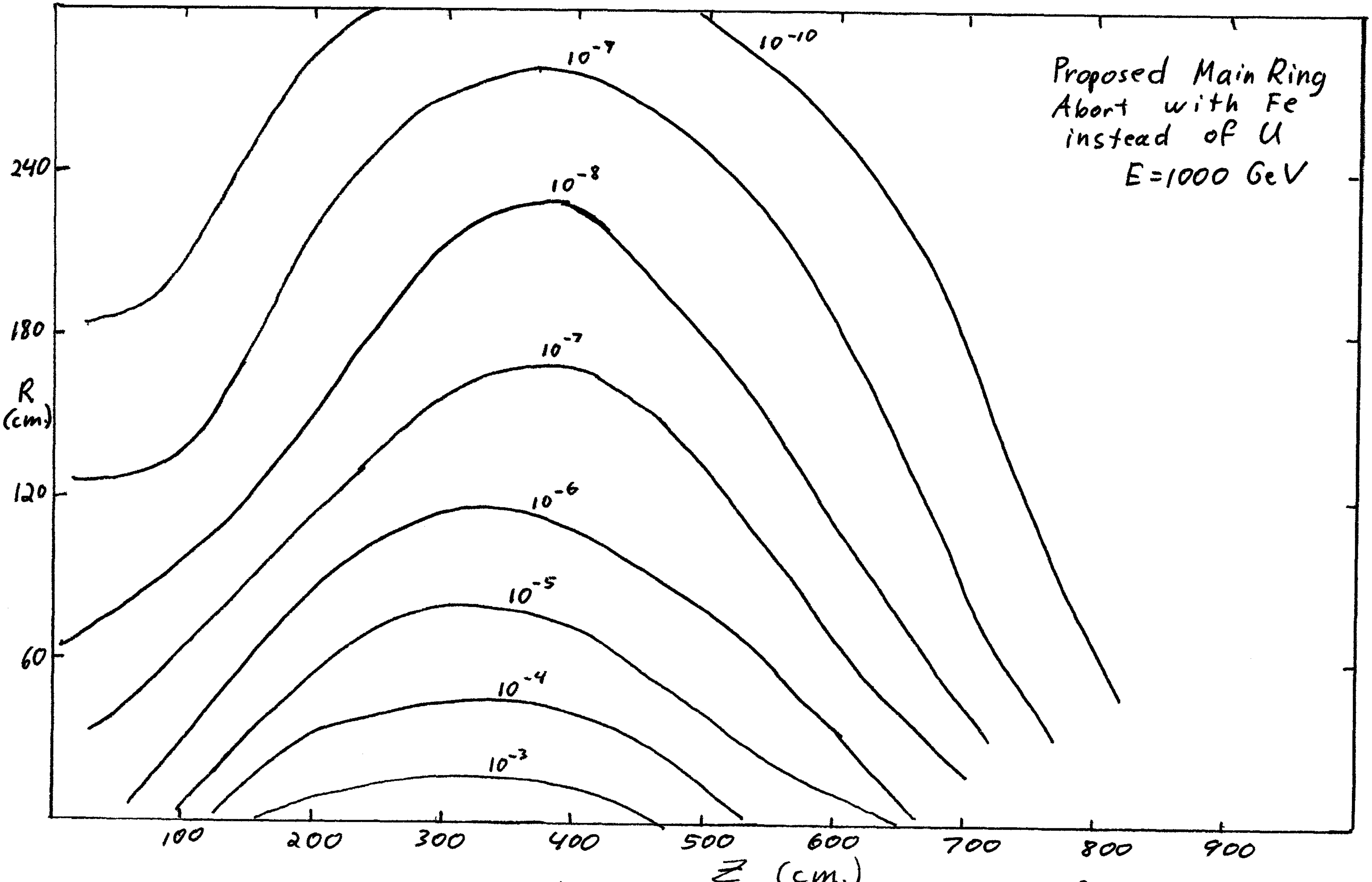
FIGURE CAPTIONS

1. Simplified geometry used in the CASIM calculations drawn to the same scale as Figs. 2, 3, and 4.
2. Contours of equal star density for the case of the abort including the iron in place of the proposed uranium.
3. Contours of equal star density for the case of the abort with lead replacing the uranium.
4. Contours of equal star density for the case of the abort including the proposed uranium.
5. Momentum spectrum of the hadrons incident on the uranium.



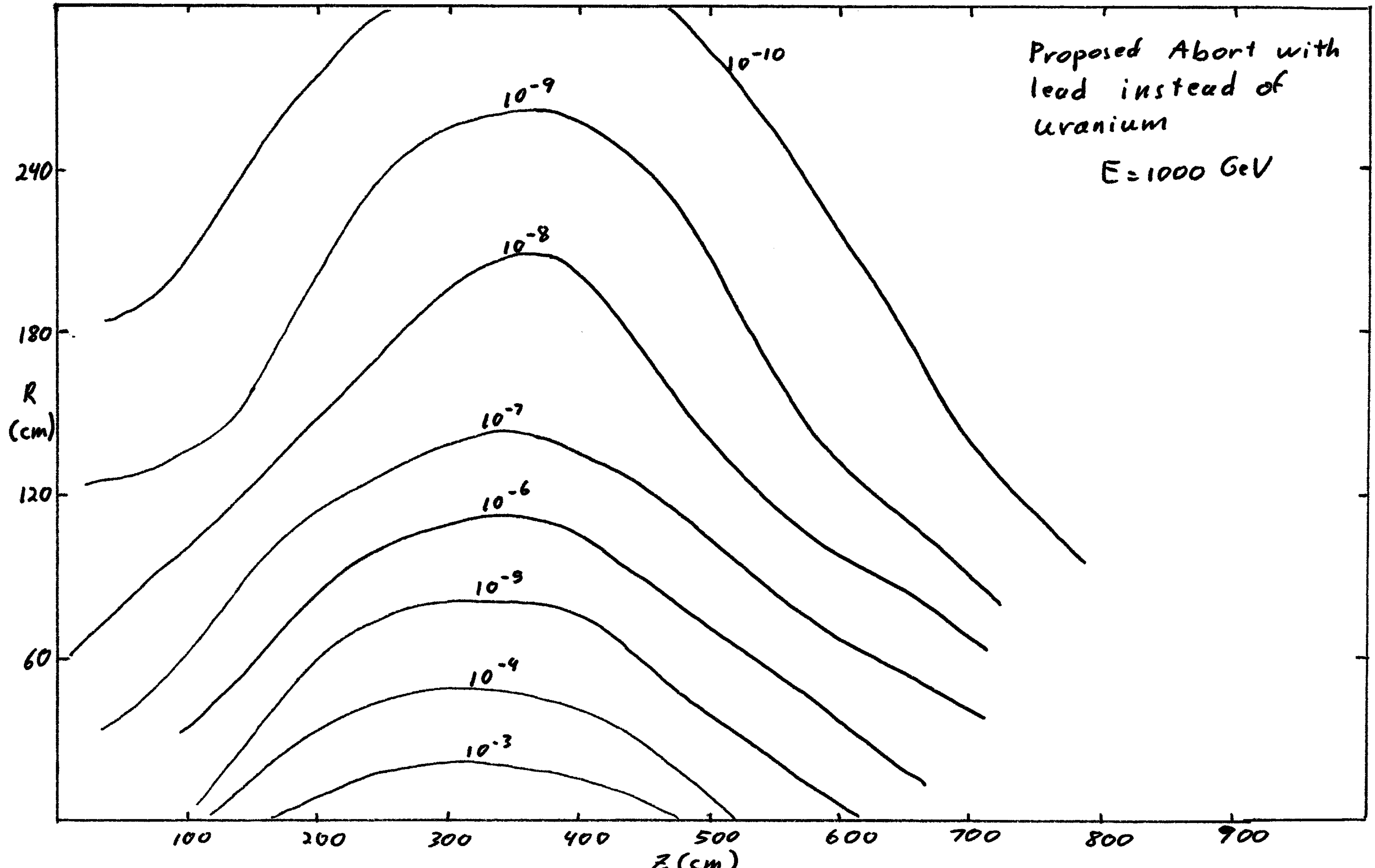
Geometry of the Main Ring Abort used in the CASIM calculation

Figure 1



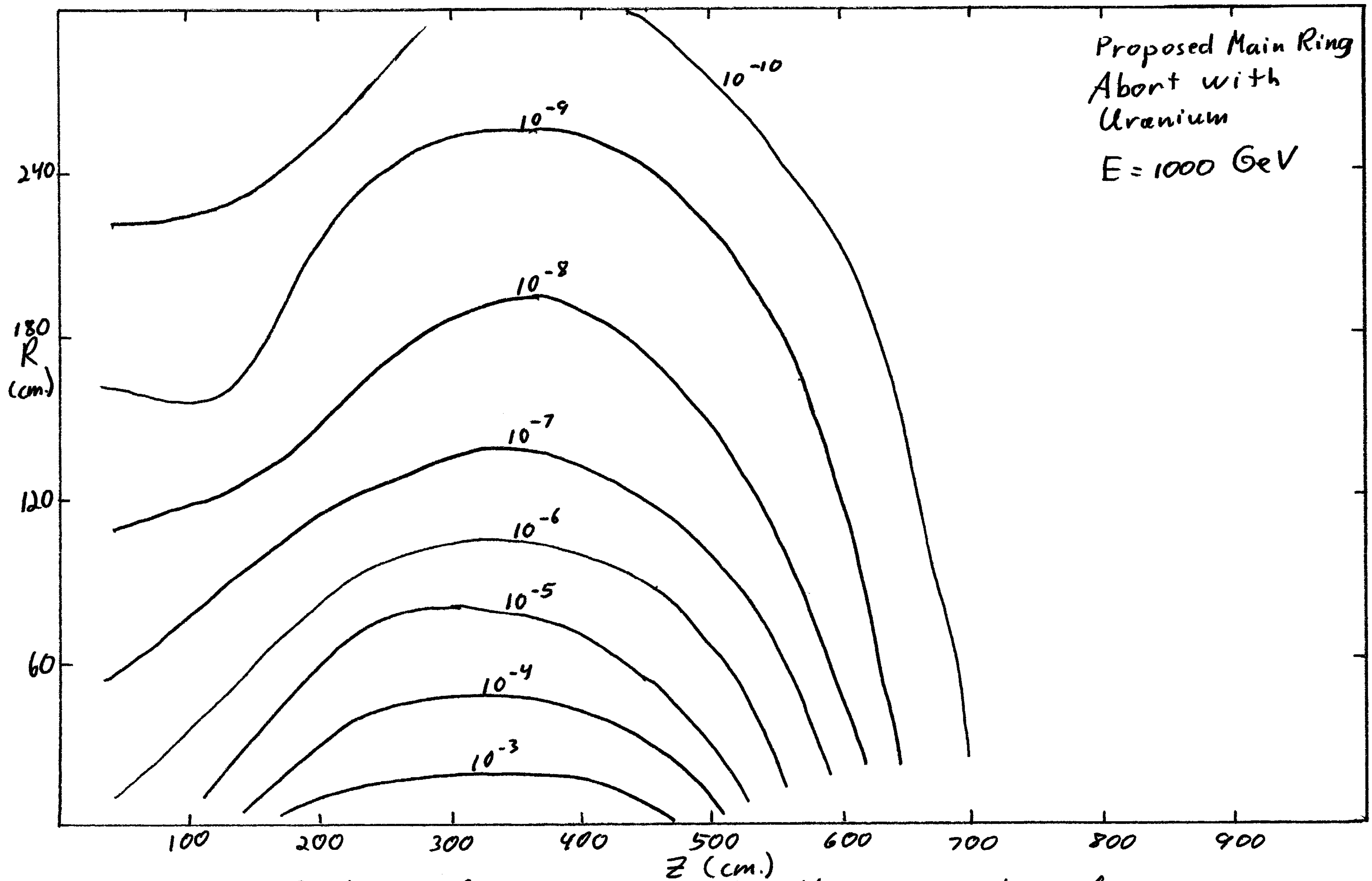
Contours of equal star density in units of stars/(cm³· incident proton)

Figure 2



Contours of equal star density in units of stars/(cm^3· incident proton)

Figure 3



Contours of equal star density in units of stars/(cm³· incident proton)

Figure 4

Spectrum of Hadrons Incident on the Uranium

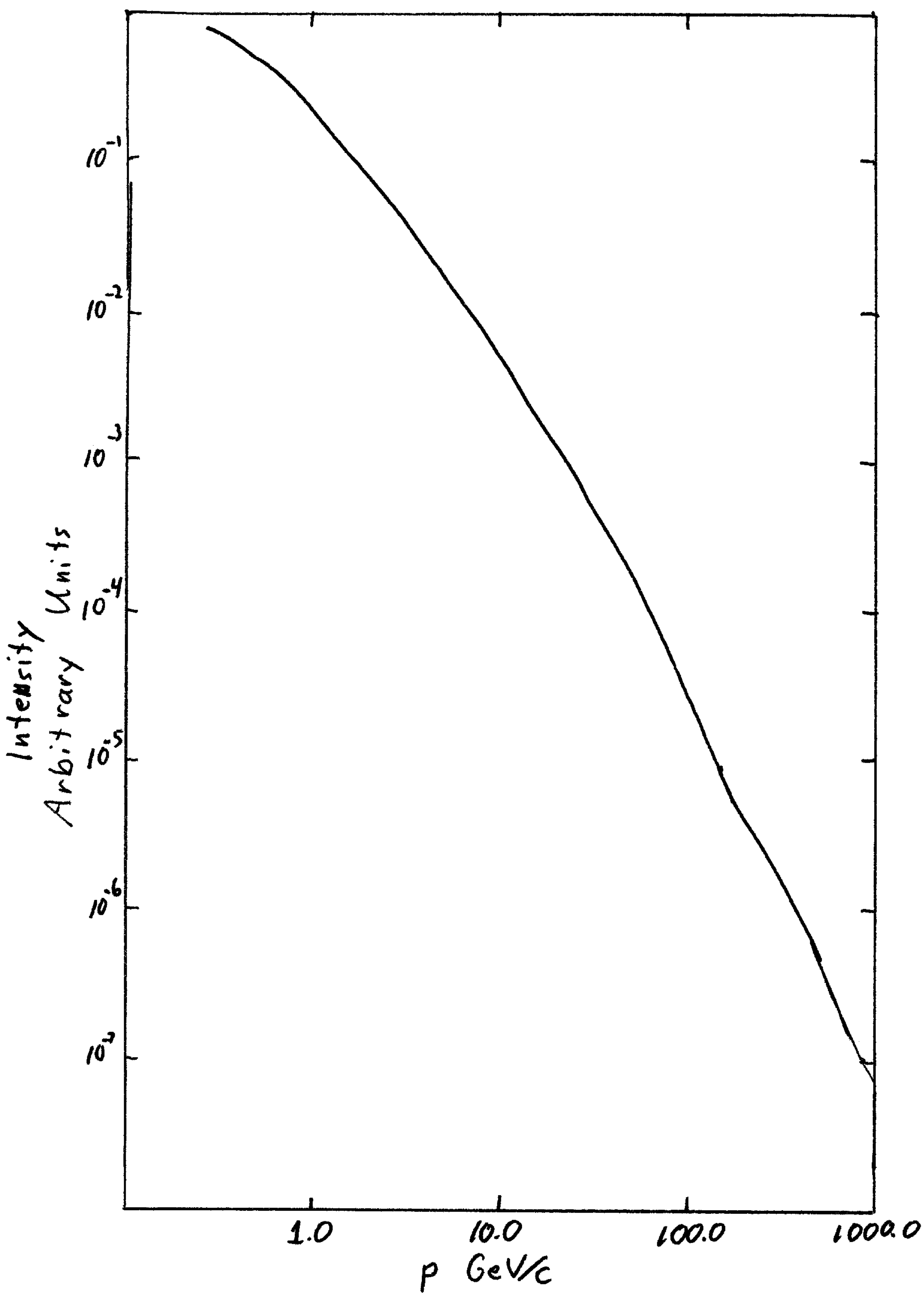


Figure 5